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This research is concerned with facilitation and interference in the identification of pictures and words. We study facilitation by presenting subjects with fragmented stimuli to identify during study, and then test the ability of various types of study stimuli to prime or improve performance on the same stimuli presented again. An important finding from our previous research is that subjects show more priming when they study a picture which is moderately fragmented during study than one which is either very fragmented or almost intact. We accounted for this phenomenon by the perceptual closure hypothesis, which says that experiencing perceptual closure, or completion of an incomplete figure during a study episode, has the most facilitative effect on subsequent identification. We study interference by presenting more degraded versions of a picture or word just prior to the identification test. Perceptual interference is generally observed if a picture or word is preceded by more fragmented versions of itself just prior to identification. Much of our work on this aspect of the research concerns discovering the reason for the perceptual interference.

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Facilitation and Interference in Identification of Pictures and Words

[F49620-92-J-0119]

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Abstract

This research is concerned with facilitation and interference in the identification of pictures and words.   We study facilitation by presenting subjects with fragmented stimuli to identify during study, and then test the ability of various types of study stimuli to prime or improve performance on the same stimuli presented again.   An important finding from our previous research is that subjects show more priming when they study a picture which is moderately fragmented during study than one which is either very fragmented or almost intact.   We accounted for this phenomenon by the perceptual closure hypothesis, which says that experiencing perceptual closure, or completion of an incomplete figure during a study episode, has the most facilitative effect on subsequent identification. We study interference by presenting more degraded versions of a picture or word just prior to the identification test.   Perceptual interference is generally observed if a picture or word is preceded by more fragmented versions of itself just prior to identification. Much of our work on this aspect of the research concerns discovering the reason for the perceptual interference.

We have made progress during the first year of funding in both these areas of research. We extended the facilitation paradigm to a number of different test situations, including picture naming, picture categorization, speeded identification, and Yes/No recognition.   Somewhat surprisingly, we failed to replicate the perceptual closure effects (better performance for a moderately fragmented study stimulus) when the test stimulus was intact.   We accounted for these results by a similarity or compatibility explanation which says that performance will be affected by the similarity of the fragmentation levels of the study and test stimuli.   When intact test stimuli were used, intact study stimuli produced the best priming or the best recognition memory performance; when fragmented test stimuli were used, fragmented study stimuli produced the best priming or the best recognition memory performance.   The similarity account transcended type of test (from implicit to explicit memory).   We extended the perceptual interference research to account for results in the literature which failed to find interference effects for words.   We showed that this failure was produced by low levels of performance — when level of performance was below some criterion level, interference failed to occur.   We were able to account for this level of performance effect within a neural network model of perceptual identification.

Facilitation and Interference in Identification of Pictures and Words
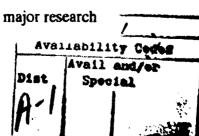
Research Objectives

This research project is concerned with long-term facilitation and short-term interference in identification of pictures and words. The long-term facilitation occurs when subject are exposed to some representation of the item during a study episode, and then show improved identification of that item during a retention test. This type of facilitation is known as long-term priming and the retention test is known as an implicit or indirect test because subjects are not instructed to think back to the prior study episode during the test. Short-term interference occurs when subjects are presented with degraded information about a target item just before being asked to identify it.

The priming paradigm we have used asks subjects to identify items presented during the study episode which vary in their level of fragmentation. Of interest is the relationship between the level of fragmentation during study and the amount of priming during test. We are also interested in the relationship between priming effects on implicit tasks, such as perceptual identification of test stimuli, and learning effects on explicit tasks, such as response accuracy or speed in recognition memory. Comparisons between implicit and explicit memory processes can shed light on what processes take place during implicit memory.

Our paradigm for studying short-term interference is to present an item for identification under each of two presentation conditions. The ascending condition presents more fragmented versions of the fragmented item immediately before the target level of fragmentation is presented while the fixed condition presents only the target level of fragmentation. Perceptual interference occurs when the ascending condition produces worse performance than the fixed condition. This occurs presumably because the prior presentations of more fragmented images have interfered with the subject's ability to identify the target level. We are interested in the generality of this effect — specifically, whether it occurs for words as well as for pictures, and what effect various parameters of the preceding presentations, such as their number or duration, have on the magnitude of the interference effect.

Here I describe our progress during the first year of funding on these two major research

areas, and also briefly describe two related areas which are spinoffs from the main research areas.

1. Short-term Interference in Picture and Word Identification

Imagine that you are walking down a street and several blocks away you see a person who appears vaguely familiar coming toward you. You would like to be able to identify the person correctly when you are within hailing distance so as to avoid either missing a friend or falsely recognizing a stranger. What should you do? Should you begin to scrutinize the face immediately and continuously as the person approaches and his facial features are slowly clarified? Or should you look away and only scrutinize the face during the last hundred feet or so before you need to make a decision? We suspect most people would opt for the first solution, even though experimental literature suggests that the second will produce better identification.

Several studies have shown that subjects' ability to identify a moderately blurred image is undermined if subjects have been cued with partial features of that image beforehand. This phenomenon, the perceptual interference effect, was explored by Bruner and Potter (1964) who showed that identification of objects which were gradually brought into focus became progressively worse as initial levels were made more blurred. They attributed this interference effect to subjects' erroneous hypotheses about the object which interfered with correct perception.

Although this phenomenon would appear to have enormous theoretical and practical implications, the perceptual interference effect was largely ignored until fairly recently. Snodgrass and Hirshman (1991) explored the perceptual interference effect in a picture fragment completion paradigm. We generated interference by preceding a moderately fragmented (level 4) picture with more fragmented levels (levels 1, 2, and 3) in an ascending method of limits procedure. This interference or ascending condition was compared to a fixed or control condition in which only a level 4 picture was presented. In a series of five experiments, we tested a number of different hypotheses about the source of the interference. We tested Bruner and Potter's erroneous hypothesis explanation by forcing subjects to generate guesses at each level of the ascending condition, and either giving subjects feedback for correctness (feedback condition) or not (no feedback condition). We found, contrary to the predictions of the erroneous hypothesis explanation, that feedback did not diminish the interference effect.

A connectionist model for picture recognition derived from the Hirshman and Gomes

(1990) word recognition model was able to produce the interference effect in a simulation. However, it did so by producing greater transient activation in features common to both target and distractor items in the ascending than fixed condition, thereby reducing the signal-to-noise ratio. In an experiment designed to test the transient activation explanation, we attempted to reduce the activation in the ascending condition by having subjects solve math problems between trials in the ascending condition. We reasoned that this manipulation would reduce activation levels in the distractor items by directing the subject's attention away from the identification task. We found, as predicted, that the math condition eliminated the interference effect.

In collaboration with one of my graduate students, Chun Luo, we have explored various parameters of the interference effect (see Luo & Snodgrass, 1993). In two experiments, we factorially varied two factors employed by Bruner and Potter in their original studies — starting point of the ascending series and viewing duration of both prior cues and the target stimulus. We found, consistent with their results, that decreases in starting point increased the interference effect. However, contrary to their results we found that viewing duration had paradoxical effects — it increased the interference effect when the viewing duration of more fragmented cues was increased, consistent with the notion that competing items to the target item were being more strongly activated. However, increases of viewing duration at the target level of fragmentation decreased the interference effect (or increased performance), consistent with the positive effects of viewing duration reported by Bruner and Potter. We view this effect as a type of "Block's Law" for identification of complex stimuli in which increases in duration of a threshold-level stimulus increases its probability of identification.

The remaining experiments in the series addressed some results reported by Peynircioglu and Watkins (1986) and Peynircioglu (1987) on word fragment completion. They observed interference effects when word fragments were presented bit by bit compared to all at once. However, the effect only occurred for studied but not for unstudied items, and for items blocked by semantic category but not for mixed items. They suggested that the interference only occurs if the target items are from a limited set. In three experiments, we showed that the crucial variable was not whether words came from a limited set but rather whether some performance threshold had been reached. Interference only occurred when identification performance was above some

moderate level (usually 50%). The manipulations used by Peynircioglu and Watkins of restricting the sets had the effect of raising performance levels, so set limitation and performance level were perfectly confounded. We accounted for these results with a competitive activation model, derived from the Hirshman/Snodgrass connectionist model, which requires that activation of competing responses attain sufficient strength to produce interference. These studies also showed that perceptual interference appears to work about the same for words as for pictures.

Neighborhood Effects

A related interference effect may be the effect of neighborhood size (the number of words similar to a target word) on the word's identification. Because our competitive activation model says that interference is caused by items similar to the target being activated by the ascending presentations, it is obviously of interest to investigate the role of having many or few similar items.

The neighborhood project came about in the following way. Meredith Poster and I carried out a norming study (Snodgrass & Poster, 1992) to obtain fragment completion thresholds for the words corresponding to the Snodgrass and Vanderwart (1990) pictures we had fragmented. In the course of preparing that paper, we explored a number of characteristics of the items to see whether any of them might account for variance in the thresholds. Among them was the variable of neighborhood size, the number of words which are similar to the target word. Neighborhood size was measured with the N-metric of Coltheart, Davelaar, Johnson, and Besner (1977) in which N is defined as the number of words which can be formed from a target by substituting one letter, preserving letter positions. We found no correlation between neighborhood size and threshold for our set of words. However, in reviewing the literature on neighborhood size effects, we were struck by the discrepancies. Specifically, Andrews (1989; 1992) reported that neighborhood size was facilitatory in a lexical decision task whereas Grainger and his colleagues (Grainger, 1990; Grainger & Segui, 1990) reported inhibitory effects of neighborhood size in the same paradigm.

Accordingly, we investigated neighborhood size, using Andrew's words, in a series of experiments which used both accuracy and speeded measures. These experiments are reported in Snodgrass and Mintzer (1993). The important result of our research was that we, like Grainger, found inhibitory neighborhood effects, but only for low frequency words. We speculated that either inhibitory or facilitatory effects might be found depending upon how liberal or conservative

the subject in the lexical decision task might be. If a subject only requires a weak signal that the stimulus is a word, but doesn't require that he identify the word, then neighborhood size might be facilitatory because a word with many neighbors looks more "word-like". However, if subjects require the stringent criterion of actually locating the word in their internal lexicon, then large neighborhoods, particularly for low frequency words, will interfere, and neighborhood size will be inhibitory.

We plan to investigate the relationship between neighborhood size and perceptual interference in future experiments. One straightforward prediction is that perceptual interference will be higher for low frequency words having many high frequency neighbors because activation of these high frequency neighbors will be particularly strong from the ascending presentations. We also plan to investigate the neighborhood size of pictures to see whether similar effects to that of words might be obtained.

2 Long-term Facilitation of Picture and Word Identification

In a series of recent experiments (Snodgrass & Feenan, 1990),we had subjects study pictures which were very fragmented, moderately fragmented, and intact and then tested them for perceptual identification by presenting old and new pictures with the ascending method of limits (most fragmented level first). Across five experiments, we consistently found that the moderately fragmented study picture produced the most robust priming. We accounted for this phenomenon by the mechanism of perceptual closure — when subjects are presented with stimuli which are just on the threshold of identification, and they experience closure by filling in the missing pieces, this provides a more powerful priming experience than either seeing a complete picture, so that no closure is experienced, or seeing a picture which is so fragmented that no closure is possible.

In a recent series of experiments we attempted to see whether the perceptual closure phenomenon would generalize across various types of implicit and explicit tests. Specifically, we looked at performance on naming of intact stimuli, speeded identification of a rapidly completing series of fragmented images, and Yes/No recognition performance of previously seen pictures. In all experiments the level of fragmentation of a studied picture was manipulated across three levels. During the study phase, subjects saw pictures which were presented at each of three levels of fragmentation — very fragmented (level 1), moderately fragmented (level 4), or virtually complete

(level 7 or 8). Subjects attempted to identify the pictures by typing their name onto a computer keyboard, and were given feedback about their correctness and told the name of the picture.

The experiments varied in the memory test. We tested memory with identification performance on fragmented versions of the studied pictures (as in the Snodgrass and Feenan experiments), speeded identification of rapidly completing pictures, naming latency on intact versions of the studied pictures, and Yes/No recognition errors and latency in a recognition memory experiment. The first three tasks are indirect or implicit tests of memory because subjects are not asked to decide whether they saw the test pictures before but only to perform the task of identification or naming on the test pictures. The fourth task is a direct or explicit test of memory because the subject must decide whether or not the picture was shown in the study episode. In all experiments, as expected, subjects performed better on the old than the new pictures (i.e., there was priming or implicit learning on the implicit tests and there was explicit learning on the recognition memory tests). The Snodgrass and Feenan results were replicated in the experiment using fragment completion as the implicit task. Subjects did better when they had studied the picture as a moderately fragmented stimulus than when they had studied the picture as either a very fragmented or almost complete stimulus. Thus accuracy of test performance was an inverted U-shaped function of study fragmentation level.

Surprisingly, however, in the picture naming experiment, the Snodgrass and Feenan results were not replicated. Instead, subjects responded fastest when they had studied the picture as an intact stimulus, next fastest as a moderately fragmented stimulus, and slowest as a very fragmented stimulus. Thus RTs decreased with study fragmentation level. A similar pattern of results was obtained for the recognition memory experiment. Subjects recognized old items better (measured both by hit rate and by hit RTs) when the studied item had been intact than when it had been moderately fragmented, and the moderately fragmented item was recognized better than the very fragmented item.

Snodgrass and Hirshman interpreted these dissociations in terms of compatibility or transfer-appropriate processing effects between study and test conditions. The logic of using an accuracy measure in a perceptual identification task requires that the test stimulus be fragmented or otherwise degraded. Thus, in the accuracy experiment, the test stimulus had to be a moderately

fragmented stimulus, and this moderately fragmented stimulus was most similar to the moderately fragmented study stimulus. In contrast, the logic of using a speed measure in a perceptual identification task requires that the stimulus be intact. Thus, in the speed experiment, the test stimulus had to be an intact stimulus which was most similar to the intact study stimulus.

In order to verify that it was the similarity of study to test stimuli which determined this dissociation rather than the use of accuracy vs. speed measures per se, Snodgrass and Hirshman conducted a third experiment having the identical study procedure but using a test procedure modeled after that of Feustel, Shiffrin, and Salasoo (1983). In this speeded identification test, subjects were shown a rapidly completing series of fragmented pictures which they were to stop as soon as they knew its identity. In this situation, the superiority of the moderately fragmented study stimulus reemerged — the speed with which the series was stopped was fastest for the moderately fragmented study stimulus, next fastest for the intact study stimulus, and slowest for the very fragmented study stimulus. Accordingly, the Snodgrass and Feenan results were obtained only when the test stimuli contained some fragmented versions of the test item. These experiments are reported in Snodgrass and Hirshman (1993).

This set of results caused us to reevaluate the perceptual closure hypothesis. Our original idea was that the experience of perceptual closure on a particular stimulus should have the effect of enhancing the effectiveness of that stimulus when it is presented again. When the study stimulus is presented again in a degraded form, it will be easier to see; when the study stimulus is presented again in an intact form, it will be faster to see. On the assumption that perceptual speed is a component in any latency measured to a test stimulus, it seems logical to expect perceptual closure to improve performance regardless of the fragmentation level of the test stimulus. However, it may be that the perceptual closure process works much more specifically, and only on the ability to experience closure when a degraded test stimulus is presented again. Alternatively, it may be that perceptual closure does produce enhancement of visual perceptual speed when the target is intact, but that this speedup is small compared to other factors, like stimulus similarity, which come to dominate it. We will, therefore, continue to explore the perceptual closure hypothesis.

An MA student of mine, Hikari Kinjo, recently completed an MA thesis in which she extended the Snodgrass and Feenan results to fragmented words. She found exactly the same

pattern of results — that identification of fragmented words is best when studied as moderately fragmented compared to either very fragmented or intact images. We are in the process of writing up these results.

Explicit Retrieval in Picture Fragment Completion

A difficult issue in implicit tests is evaluating whether explicit retrieval processes contribute to performance on implicit tests. The enclosed paper by Hirshman and Snodgrass (1993) reports a series of experiments in which the nature of the retrieval instructions are manipulated to determine the extent to which two important manipulations in both implicit and explicit memory — the generation effect and the modality effect — are sensitive to retrieval instructions. Subjects given explicit retrieval instructions are told that many of the items on the indirect memory tests were presented during study and that they should try to think back to the study episode when performing the task. Subjects given normal instructions are simply told to perform the task, and are not told anything about the relationship between the study and test items. We anticipated that giving explicit retrieval instructions would improve overall performance across all conditions, as indeed it did. However, of primary interest was whether the explicit instructions would enhance the effect of the variable of interest — i.e., generation and modality effects.   Surprisingly, even though generation is a preeminent variable in explicit memory tasks, the generation effect on picture fragment completion (filling in the name of a picture in a sentence vs. reading the name of the picture within the sentence) was not enhanced under explicit compared to implicit instructions. In contrast, the modality effect (superior performance on picture fragment tests when pictures compared to words were used at study) was enhanced by explicit retrieval instructions. This effect is counterintuitive and also is contrary to the notion that implicit perceptual learning depends upon data-driven as opposed to conceptually-driven processing. We believe our method of evaluating whether the effect of an independent variable is enhanced or not by explicit retrieval processes offers great promise for evaluating the role of explicit retrieval processes on implicit tests.

Cattell Equivalence

In the course of carrying out the experiments described in Snodgrass and Hirshman (1993), we developed a concept which we call Cattell Equivalence. Cattell Equivalence is a principle designed to unite data on performance error with data on performance speed. Cattell Equivalence

says that errors and time are two expressions of the same underlying process. Imagine that two sets of conditions have been constructed so that one set leads to a high error rate so that errors are the dependent variable, while the other set leads to error-free response so that RTs are the dependent variable. Cattell Equivalence is defined as obtaining the same relationship between the manipulated variable of interest and each of these dependent variables.

In the experiments described in Snodgrass and Hirshman, the two sets of conditions were constructed by using fragmented test stimuli for the error-prone situation and intact test stimuli for the error-free situation. Because stimulus similarity between study and test versions of the items was completely confounded with our ability to construct the two situations, we were unable to show Cattell Equivalence in the Snodgrass and Hirshman experiments. That is, the relationship of error performance to study fragmentation level (the independent variable of interest) was U-shaped, while the relation of RT performance to study fragmentation level was decreasing.

However, because the concept unites the two most common dependent variables in experimental psychology, my students and I carried out a review of three areas of research to see what the status of Cattell Equivalence was in the literature. The three areas were psychophysics, semantic memory (word and picture recognition), and episodic memory. We concluded that there was strong theoretical and empirical support for Cattell Equivalence, and also, that when Cattell Equivalence is violated (as it was in the Snodgrass and Hirshman experiments), this signals that something else is going on. We believe that violations of Cattell Equivalence can be particularly instructive about the particular processes underlying cognitive phenomena. This paper is in the last stages of being completed and will be submitted to *Psychological Review*.

What variables affect picture naming?

A final spinoff from the major research effort concerns the factors which affect picture naming. In Snodgrass and Hirshman, we added the picture naming paradigm to our arsenal of implicit memory tasks because it seemed the most comparable speeded task to picture fragment completion, the task we had used extensively in previous work. Investigators have long been interested in studying processes underlying the cognitive operation of picture naming. As a review of the literature will reveal, however, the picture on picture naming is far from clear.

Because the 260 pictures from the Snodgrass and Vanderwart (1980) standardized set have

become the most commonly used set of pictures in cognitive research, we have decided to obtain normative data on naming latencies and errors to the entire set of pictures. This project is being carried out in collaboration with one of my graduate students, Tanya Yuditsky. These data are presently being collected and will be used for the following purposes: first as a published data base for other investigators in the field, and second, as a set of data to explore various hypotheses about the processes involved in picture naming.

Most models of picture naming propose that the process entails at least three steps: accessing the visual features or stored structural description of the item; accessing the item's meaning or its semantic representation; and accessing its pronunciation or phonological representation (Humphreys, Riddoch, & Quinlan, 1988). One of the challenges to accounting for picture naming data is determining whether these hypothetical stages can account for variance in picture naming latencies produced by either item-specific variables such as frequency in print of the picture's name or age of acquisition of the concept name or by experimenter-manipulated variables such as repetition priming effects or short-term associative priming effects.

We hope to approach this question in two ways. First, we plan to analyze the normative naming latencies we obtain with the methods of multiple regression to see which if any of the variables we have measured on the pictures account for picture-naming variance. Second, we plan to carry out a series of short-term priming experiments, in which a picture is primed in one of three ways: with its first letter (which should speed the phonological component most); with its category (which should speed the semantic component most); and with its level 1 fragmented image (which should speed the structural component most). These priming manipulations will be crossed with pictures whose measured characteristics are either high or low on the naturally occurring picture variables which we have determined to be of importance in picture-naming.

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Papers published, in press, or submitted resulting from this grant (starred papers are included)

*Snodgrass, J. G., & Poster, M. (1992). Visual word recognition threshouds for screen-fragmented names of the Snodgrass and Vanderwart pictures. *Behavior Research Methods, Instruments, and Computers, 24*, 1-15.

*Snodgrass, J.G., & Mintzer, M. (1993). Neighborhood effects in visual word recognition: Facilitatory or inhibitory? *Memory & Cognition*, In press.

*Snodgrass, J. G., & Hirshman, E. (1993). Dissociations among implicit and explicit memory tasks: The role of stimulus similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Under review.

*Luo, C. R., & Snodgrass, J. G. (1993). What factors affect perceptual interference? *Journal of Experimental Psychology: Human Perception and Performance*, Under review.

*Hirshman, E., & Snodgrass, J. G. (1993). Examining the role of explicit retrieval processes in picture fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Under review.

Luo, C. R. (1993). Enhanced feeling of recognition: Effects of identifying and manipulating test items upon recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, In press.

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Snodgrass, J. G., Dalton, P., Mintzer, M., & Luo, C. R. (1993). Cattell equivalence: A comparison of accuracy and speed functions. Submitted to *Psychological Review*.

Conference Presentations resulting from this grant

Snodgrass, J. G., & Mintzer, M. Neighborhood effects in visual word recognition: Facilitatory or inhibitory? Paper presented at the annual meeting of the Eastern Psychological Association, Boston, MA, April, 1992.

Snodgrass, J. G. (1993). Translating vs. Picture Naming: Similarities and Differences. Presented at an international conference on the bilingual lexicon in Kerkrade, Holland, July, 1992.

Snodgrass, J. G., & Luo, C. R. What factors affect perceptual interference? Paper presented at

the thirty-third annual meeting of the Psychonomic Society, St. Louis, MO, November, 1992.

Names of participating professionals

1. Elliot Hirshman, Assistant Professor, Department of Psychology, University of North Carolina
at Chapel Hill (consultant, co-author on one or more papers, collaborator)

2. Chun Luo, Graduate Student, doctoral program, Department of Psychology, New York
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3. Pamela Dalton, Graduate Student, doctoral program, Department of Psychology, New York
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4. Miriam Mintzer, Graduate Student, doctoral program, Department of Psychology, New York
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5. Meredith Poster, Graduate Student, MA program, Department of Psychology, New York
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6. Hikari Kinjo, Graduate Student, MA program, Department of Psychology, New York
University (collaborator, research assistant, co-author on one or more papers).

7. Two undergraduate tutorial students and three high school students from Stuyvesant High
School participating as part of their Westinghouse Project.